MARCH, 1916 BULLETIN 210

VIRGINIA POLYTECHNIC INSTITUTE
VIRGINIA AGRICULTURAL EXPERIMENT STATION

A Typical Elberta Tree, as Used in These Experiments. The Ideal Form of Tree for Commercial Work.

A Stone-Fruit Spray Made From Hydrated-Lime and Sulphur

BY

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BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

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A STONE-FRUIT SPRAY MADE FROM HYDRATED-LIME AND SULPHUR.

By G. C. Starcher.

For years horticulturists have been looking for a satisfactory spray for stone-fruits, but none has been found. Bordeaux mixture and also concentrated lime-sulphur burn the foliage. Self-boiled lime-sulphur is highly variable in strength. It may be so weak as to be ineffective or strong enough to burn both fruit and foliage. The combination spray of atomic sulphur and arsenate of lead, which is sometimes used for curculio, occasionally burns the foliage. Sulphur alone used as a liquid spray requires either soap or glue in mixing, and when used as a dust spray it necessitates the purchase of a powder gun. Most of our fruit growers are unfamiliar with dust spraying and do not want to buy a new kind of spray machine. When sulphur is used in combination with arsenate of lead as a dust spray there may be some danger of burning.

What stone-fruit growers have wanted is a spray mixture with the virtues of all the spray materials now in use and with as few as possible of their faults. The ideal spray solution should be effective, easy to make, easy to apply, inexpensive, relatively constant in strength, and as free as possible from materials which stain the fruit. It should also combine with an arsenical poison without injury to the foliage and fruit.

The Experiment Station has studied this problem for some time and while it is too soon to make a final report, the results secured in 1915 warrant the publication of this paper. Further experiments will be necessary to perfect this fungicide but as at present made it has advantages over any other spray that we have used.

Up to the present time self-boiled lime-sulphur (Scott's Formula) has embodied the requirements enumerated above to a greater degree than other stone-fruit sprays, but it is not easy to make or to apply, and moreover it is never constant in strength. Its variability is due to the quality of the lime used, the amount of slaking that has taken place, manner of handling the lime, the temperature of the water used and the amount made up at one time. In laboratory work we found that in making self-boiled lime-sulphur the solution when free from sediment tested from zero to two degrees Beaumé when six times usual strength. It was impossible to overcome this variation. When water at 60° F. was used to slake the lime, not enough heat was produced to bring the water to the boiling point. When water at 160° F. was used with one lot fair results were secured in five minutes, but

when another lot was made, of the same kind of lime, even when using boiling water, slaking was not complete for fifteen minutes. This lot was so strong that it would have been dangerous to use.

In addition to the great variability of self-boiled lime-sulphur it also often stains the fruit badly. Other difficulties with self-boiled lime-sulphur are met with in straining the spray mixture, and in the clogging of the nozzles and valves of the pump. Both of these difficulties are hard to overcome on account of the variability of stone lime and on account of the air slaking which nearly always takes place where stone lime is kept for any length of time. It is also difficult to prevent sulphur lumps from forming and these lumps are largely responsible for the difficulties met with in straining.

In attempting to correct the difficulties incident to the manufacture of self-boiled lime-sulphur it occurred to us that if hydrated lime (a form of lime which with proper precaution, can be kept during the spraying season without deterioration) were substituted for stone lime and a sufficient amount of boiling water were used to mix these two materials, that the heat of the slaking lime could be closely approximated, and the desired amount of the sulphides of lime could, in that way, be brought into solution. We realized that if such proved to be the case that a fungicide could be made which would be relatively uniform in its composition, since boiling water yields a fairly constant amount of heat if allowed to stand a certain number of minutes before cooling. It was also apparent that if hydrated-lime and powdered sulphur were used that the resultant product should be easy to strain and that it could be applied without clogging the pump or nozzles. It was found that the substitution of hydrated-lime would not greatly increase the cost of the spray, especially when the loss sustained by the slaking of stone lime was taken into account. In other words, it appeared that such a spray would have all the virtues of the self-boiled lime and sulphur and that its undesirable qualities would be materially reduced or entirely eliminated. It would be as easy to apply as atomic sulphur and less expensive. Used in combination with arsenate of lead it would have enough lime to counteract the burning of the free arsenic, provided the proper amount of arsenate of lead was used. Furthermore, the solution could be made of any desired strength by modifying the formula or changing the time of cooking.

It was decided to give this spray mixture a trial during the season of 1915. A certain plat of peaches, mostly of the Elberta variety, owned by the Virginia Agricultural Experiment Station at Crozet, Albemarle County, Va., was selected for the purpose and the crop on a White Heath Cling peach orchard of some two hundred trees at the same place was purchased in order to obtain additional facilities for testing this spray.

The Elberta orchard was bearing its first crop. It was located on rather low land with only fair air drainage. Scab had been observed on the branches, so an attack of this disease was naturally expected.

FIELD EXPERIMENTS.

Hydrated-Lime and Sulphur Compared with Other Sprays on Elbertas.

The following is a brief summary of the experiments with this variety. The trees which were mostly Elberta were divided into five plats, and were sprayed as follows:

Atomic Sulphur, Three Applications.—Five pounds Atomic sulphur and three pounds of paste arsenate of lead to fifty gallons of water were applied as soon as the petals were all down, May 4th and again on May 29th. On July 22nd they were sprayed again, but with the arsenate of lead left out.

Self-Boiled Lime-Sulphur, Three Applications.—Eight-eight-fifty self-boiled lime-sulphur and three pounds of paste arsenate of lead were applied on the same date as above, and with the lead left out of the July 22nd application.

Hydrated Lime-Sulphur, One Application.—Hydrated lime-sulphur made up as follows: Twelve pounds hydrated-lime, eight pounds sulphur, eight gallons boiling water (later diluted to fifty gallons), and three pounds paste arsenate of lead. The lime and sulphur were first mixed dry, then the eight gallons of boiling water were added by mixing the lime and sulphur to a paste as quickly as possible with two gallons boiling water (see laboratory experiments), then adding the other six gallons and stirring the mixture for five minutes. This material was then cooled quickly by the addition of an equal amount of cold water and then diluted to forty-eight gallons, after which the arsenate of lead was added in two gallons of water. This plat was also sprayed on May 4th.

Hydrated-Lime and Sulphur, Two Applications.—This plat was also sprayed first on May 4th with the same material that was used in the previous experiment, and again on May 28th, but using ten gallons boiling water instead of eight, and two and one-half pounds of arsenate of lead instead of three pounds.

Hydrated-Lime and Sulphur, Three Applications.—This plat was sprayed exactly as the previous plat with an additional application of the same material, but without arsenate of lead, on July 22nd.

Results.

Atomic Sulphur, Three Applications, gave excellent protection from disease, as only one fruit was found showing any disease and it had only a

few scab spots. There was, however, a considerable amount of foliage injury on the Elberta and a much greater amount on a few Early Crawford and Hiley Belle trees included in this plat.

Self-Boiled Lime-Sulphur, Three Applications.—The results were perfect, except in some low moist ground where the trees had a dense foliage. A few peaches there showed scab. The foliage, however, was practically perfect on the entire plat.

Hydrated-Lime and Sulphur, One Application.—One hundred percent of the fruit was infected by scab, but there was no foliage injury.

Hydrated-Lime and Sulphur, Two Applications.—This plat showed perfect freedom from disease. There was considerable foliage injury on three heavily laden unpruned trees. There was, however, no injury whatever on the pruned trees in the same plat.

Hydrated-Lime and Sulphur, Three Applications.—The fruit on this plat was free from disease. There was a small amount of foliage injury on some heavily laden unpruned trees, but not a trace of injury showed where the trees had been properly pruned.

The spray injury occurring on the Atomic sulphur plat was noted on both the pruned and unpruned trees. There were no unpruned trees in the self-boiled lime-sulphur plat. There was so little curculio in all of the various plats that no attempt was made to ascertain the extent of injury from this source. Brown rot did not occur. No check plat was left, as other experiments in the orchard were of such importance that unsprayed trees would endanger this work.

The fact that every peach on the plat which received but one application of hydrated-lime and sulphur at the time the shuck still covered the newly set peach, was affected with scab, shows the abundant presence of this disease. Two sprayings, however, showed absolute control of scab. All trees had received a spray of winter strength concentrated lime and sulphur.

Hydrated-Lime and Sulphur Compared with Other Fungicides on White Heath Peaches.

The crop on the White Heath orchard had been partially destroyed every year for three years by brown rot and scab. Hundreds of brown rot mummies from the previous year were still clinging to the branches at the time our work was begun. Hundreds more were on the ground. No winter spray had been applied. The White Heath is very susceptible to brown rot and to scab. Therefore, here were conditions which would put any spray material to a crucial test. The mummies on the trees were carefully gathered and destroyed and the entire orchard was cultivated so as to destroy or cover up as far as possible those on the ground. This orchard of twelve rows was divided into six plats, five of which were used as spray

plats and one as a check. The treatment of the plats was as follows: First application as soon as petals fell, on May 1st; second, May 28th; third, July 22nd; fourth, August 17th. Three pounds of paste arsenate of lead were used in all spray materials for the first and second applications. None was used in the last two sprayings.

Self-Boiled Lime-Sulphur Plat.—For the first, second and third sprayings, Scott's eight-eight-fifty formula was used. For the fourth spraying a six-six-fifty formula of the same material was used.

Atomic Sulphur Plat.—All four applications were made, using five pounds of Atomic sulphur to fifty gallons of water.

Plat One of Hydrated-Lime and Sulphur.—For the first application the spray was prepared as follows: Eight pounds flowers of sulphur and twelve pounds hydrated-lime were mixed in hot water and heated over fire for twenty minutes until brought to the boiling point, after which water was added to make fifty gallons.

For the second and third spraying the same amounts of hydrated-lime and sulphur were used, but eight gallons boiling water was added and allowed to stand in covered tub for five minutes, and then diluted with forty-two gallons cold water; the arsenate of lead being mixed with two gallons of this amount.

Fourth spraying, six pounds sulphur, nine pounds hydrated-lime mixed as were the second and third applications.

Plat Two of Hydrated-Lime and Sulphur.—For the first, second and third spraying, eight pounds flowers of sulphur, twelve pounds hydrated-lime, eight gallons boiling water were used. Materials mixed and allowed to stand in covered tub for five minutes, when forty-two gallons of cold water was added.

Fourth spraying; six pounds sulphur, nine pounds hydrated-lime, eight gallons boiling water allowed to stand ten minutes before cooling.

Concentrated Lime-Sulphur.—One-half gallon of lime-sulphur solution and twelve pounds hydrated-lime were added to enough water to make fifty gallons of spray material. Used first spray only. For the second, third and fourth treatments the same amount of concentrated lime-sulphur, but only six pounds of hydrated-lime, were used.

Check.—Not sprayed until July 22nd, at which time at least 99 percent of the fruit showed scab and it was considered wise to spray to hold scab partially in check and to try to prevent a brown rot outbreak which would unnecessarily menace the rest of the orchard.

Results.

The season, on account of continuous rain during much of the growing period, was most favorable for the development of brown rot and scab.

Rainy weather following a brief drouth caused a large number of fruits to crack on all of the plats. Owing to the brown rot mummies on the ground, and infection from the unsprayed plat, it was impossible to prevent infection by this disease in these cracks. It is probable that the loss from this source was two percent of the crop. However, not one-tenth of one percent loss resulted from brown rot infection on fruit which did not first crack. Scab infected at least 99 percent of the fruit on the check plat. Only one clean fruit was seen, and much fruit rotted in spite of two sprayings.

Not one percent of the fruit on any spray plat showed scab infection, and none was discarded on account of scab.

The check plat was badly infested by curculio, but no count was made of the curculio injury on any of the plats.

No appreciable spray injury on the foliage was noted on any plat except on a few leaves in plat four, where concentrated lime and sulphur was used. Spray injury on the fruit was found only on the sunny side of a few of the most exposed peaches. The latter injury was apparently uniform on all plats.

The first plats to ripen were the check and Atomic sulphur plats. The last to ripen was the self-boiled lime-sulphur plat. The other three ripened together. The reason for the difference noted in time of ripening was not determined.

The least amount of stain was noted on the Atomic sulphur plat, but on this plat all observers agreed that neither the foliage nor the fruit was as good in appearance as on the other plats. Very little stain was observed on the other plats; not enough in any case to cause the least damage.

LABORATORY EXPERIMENTS.

The next problem was to determine the constancy of the hydrated-lime and sulphur solution when made according to the formula given above and to investigate the various other problems that presented themselves during the summer season. A series of laboratory experiments were carried out, the most important of which are here given.

Materials Used in Laboratory Tests.

Two grades or forms of sulphur were used; the ordinary commercial ground sulphur and superfine sulphur. The latter was donated by the Union Sulphur Company of New York City. It was a very finely pulverized material, and one would naturally expect it to give better results than would be secured by using the coarser ground article, known as commercial ground sulphur. Such was not found to be true, however, since it was difficult to prevent the formation of lumps immediately after the super-

fine sulphur was passed through a sieve. It was almost impossible to wet these lumps even when mixed with hydrated-lime, and no matter how thoroughly the mixture was stirred, the lumps would not break up and did not pass through the strainer freely. The commercial ground sulphur was, on the other hand, when used with the hydrated-lime, very easy to mix with water and readily passed through the strainer. It is probable that if a suitable apparatus can be devised in which the superfine sulphur and hydrated-lime in correct proportions can at one and the same time be mixed and sieved, superfine sulphur will be preferable to the commercial or ground sulphur. At the present time, the price of the superfine article is much greater than the commercial sulphur and unless further experiments demonstrate that it has superior qualities there is no reason why it should be recommended.

The Security Cement and Lime Company of Hagerstown, Md., donated a part of the hydrated-lime used, and the rest was purchased from the Riverton Lime Works, Riverton, Va. Both limes gave excellent results. Neither lime required sieving, but they were sieved to be sure there were no lumps or other material which would not pass freely through a sieve or strainer.

By consulting the detailed laboratory experiments it will be observed that nearly all the material which went into solution did so in the first five minutes. By noting the temperatures it will be seen that the action was very slow after the material had cooled to 170° F. When water in equal amounts but of different temperatures is mixed, the resultant temperature is the average of the two. In other words, if eight gallons of water at a temperature of 60 degrees is added to eight gallons of solution at 170 degrees the temperature will be reduced to about 115 degrees; a temperature at which very slight chemical action takes place.

Some Laboratory Experiments in Detail.

The first laboratory experiments were begun March 27, 1915. At that time, however, it was attempted to heat the material over a fire for a certain length of time. This was soon found to be impracticable and it was then that the idea of utilizing the heat of boiling water instead of fire or slaking lime was conceived.

All hydrometer readings which follow are made at six and one-fourth times the strength at which the fungicide would be applied to the trees. All samples were cooled quickly after taking.

EXPERIMENT NO. I.—*To Ascertain the Range in Strength and Variability of Material Used in 1915 Field Experiments.*

MATERIALS— 8 lbs. commercial ground sulphur.
10.6 lbs. hydrated-lime. (The equivalent of 8 lbs. stone lime.)
8 gallons boiling water.

Sample No. 1 taken at 5½ minutes. Clear solution after standing 24 hours gave a reading on the Beaumé hydrometer of .3 of one degree.

After 10 days .6 of one degree.

" 26 " 1.0.

The second and third samples show that the lime and sulphur continue chemical action when standing.

This lot was made in a covered vessel and was not agitated except when sample was taken. It showed only a very small amount of material in solution at five and one-half minutes, or after twenty-six days. If at twenty-six days five and one-fourth parts of water were added the strength would be only a little over one-tenth of one degree Beaumé or one-fourth as strong as a solution made up from one and one-fourth gallons of commercial lime-sulphur at thirty-three degrees Beaumé and forty-eight and three-fourths gallons water, this being the proper mixture for the regular summer spray for apples. It remains to be seen whether or not the spray should be used at once or whether it can be allowed to stand a few days. The ease with which the material can be prepared, however, renders it unnecessary to make up stock solutions. This undoubtedly shows the approximate strength of the material that was used in the field experiments. Later laboratory results support this conclusion.

EXPERIMENT NO. II.—*To Note Comparative Results when Superfine Sulphur Was Used Instead of Commercial Ground Sulphur.*

MATERIALS— 8 lbs. superfine sulphur.
10.6 lbs. hydrated-lime.
8 gallons boiling water.

Sample No. 1 at 5 minutes. Clear solution after 24 hours gave a reading of .25 of one degree. At ten days no change could be noticed in a 20-minute sample. No other sample was kept.

This sample shows almost the same strength as that secured by using commercial ground sulphur, but it was much more difficult to strain on account of the lumps of sulphur. This difficult has already been mentioned, but it may be overcome by sieving the two materials after mixing them.

EXPERIMENT NO. III.—*To Show Result of Stirring the Material After Boiling Water Is Added, Instead of Allowing It to Stand in Covered Vessel Without Agitation.*

MATERIALS—8 lbs. superfine sulphur.
8 lbs. hydrated-lime.
8 gallons boiling water.

SAMPLE	LENGTH OF TIME STIRRED	TEMPERATURE AT END OF PERIOD	BEAUMÉ READING AFTER 24 HOURS	BEAUMÉ READING AFTER 7 DAYS
No. 1	5 minutes	170° F.	.4 of one degree	.4 of one degree
No. 2	10 "	155° F.	.55 " " "	.55 " " "
No. 3	15 "	140° F.	.65 " " "	.6 " " "

The spray mixture when stirred had in five minutes as much lime and sulphur in solution as the other samples had in twenty minutes when allowed to stand without stirring. This result was verified by repetition of the experiment. A record of the temperature of the solution was secured when each sample was taken.

No appreciable change could be noted in ten days.

EXPERIMENT NO. IV.—*To Test Relative Ease of Mixing Superfine Sulphur and Commercial Ground Sulphur.*

MATERIALS
- a. 8 lbs. superfine sulphur. 8 lbs. hydrated-lime. 8 gallons boiling water.
- b. 8 lbs. commercial ground sulphur. 8 lbs. hydrated-lime. 8 gallons boiling water.
- c. 8 lbs. superfine sulphur. 8 lbs. hydrated-lime. 8 gallons soapy boiling water.

The sulphur in lot (a) was very difficult to mix and much sulphur came to the surface.

The materials in lot (b) were mixed with perfect ease with no floating sulphur. The materials in lot (c) mixed with ease. No floating materials of note.

No difference could be noted in the samples at twenty-four hours, the floating sulphur having finally settled.

A field test must show superfine sulphur to have advantages before the extra expense of purchase and trouble of mixing would be worth while.

EXPERIMENT NO. V.—*To Ascertain Effect of Reducing the Amount of Lime.*

a. 8 lbs. commercial ground sulphur. 8 lbs. hydrated-lime. 8 gallons boiling water.				b. 8 lbs. commercial ground sulphur. 5 lbs. hydrated-lime. 8 gallons boiling water.			
SAMPLE	LENGTH OF TIME COOKED	TEMP. AT END OF PERIOD	BEAUMÉ READING AFTER 24 HOURS	SAMPLE	LENGTH OF TIME COOKED	TEMP. AT END OF PERIOD	BEAUMÉ READING AFTER 24 HOURS
1	5 min.	170	.35 of one degree		5 min.	172	.45 of one degree
2	10 "	155	.45 " " "	1	10 "	155	.45 " " "
3	15 "	144	.45 " " "	2	15 "	144	.45 " " "
4	20 "	134	.45 " " "	3	20 "	136	.5 " " "
5	25 "	125	.5 " " "	4	25 "	120	.5 " " "
				5			

The results show that but little if any change in amount of the material in solution is made by reducing the amount of lime from eight pounds to five pounds. The temperatures of the various solutions are also very constant. It is also clearly shown that most of the material which goes into solution does so in the first five minutes; in lot (a) seventy percent and in lot (b) ninety percent. These results were verified by repetition of experiment many times. Since Atomic sulphur, used at the rate of five pounds to fifty gallons of water, can hardly contain more than three pounds of sulphur and little or no lime, it would seem that not over five pounds of lime is needed in this new method of preparing a lime-sulphur spray. This would reduce the danger of staining the fruit by a late spray. Further field experiments will have to be made in order to determine just how small an amount of both materials can be used at any time in the season and still give certain protection. The fungicide may also have a field of usefulness beyond that of a stone-fruit spray.

EXPERIMENT NO. VI.—*This Experiment Was Made to Ascertain Whether or Not It Is Necessary to Mix the Lime and Sulphur to a Paste When the Two Materials Are Thoroughly Mixed in the Dry State.*

MATERIALS—8 lbs. commercial ground sulphur.
5 lbs. hydrated-lime.
8 gallons boiling water.

It had been previously noted that as soon as powdered sulphur and hydrated-lime were mixed together dry, both mixed to a paste easily. In the field experiments and in the laboratory work the two materials were always first mixed into a paste and then the rest of the boiling water added. This made the time of making more difficult to record and it took longer to mix the materials than it would if the mixing to a paste were unnecessary.

In this experiment all the water was at once poured into the vessel containing the mixed hydrated-lime and sulphur. No trouble was experienced in mixing the material with water, and a sample taken at five minutes gave a reading of .4 of one degree Beaumé, which is the same reading secured by the former method time and again. A straining test was made five days later and showed only a very small amount of sulphur in lumps that would not readily pass through a strainer. A little time was saved and it would seem that this method would prove a little more accurate. However, greater care must be taken to see that the lime and sulphur are carefully sieved and mixed before the water is added.

CONCLUSIONS AND RECOMMENDATIONS.

While this fungicide has been tested for only one season, the results secured have been very gratifying and as the preparation seems to possess several important advantages over those sprays now employed it is recommended to peach growers for trial. The directions for making the spray should be carefully followed, and its use should be limited to only a few trees until fruit growers have demonstrated that there is no danger of injury to the fruit and foliage.

If growers wish to try the hydrated-lime and sulphur spray they should be sure to secure fresh hydrated-lime at the beginning of the season, and keep it in a close package away from the air. It will thus keep for several weeks without material deterioration. It should be remembered, however, that neither hydrated nor stone lime should be purchased for use in making up spray materials without a guarantee of purity. Stone lime should contain ninety-five percent calcium oxide and hydrated-lime nearly as high percentage of calcium hydrate.

In making up the spray the sulphur and hydrated-lime should be sieved after mixing them and before adding the boiling water. *Do not allow the mixture to stand more than five minutes after adding the boiling water before cooling by adding cold water.* Use eight pounds of sulphur, eight pounds hydrated-lime and eight gallons boiling water and stir for five minutes, then add cold water at once. This spray must be kept thoroughly agitated while spraying.

The Virginia Agricultural Experiment Station will continue to conduct experiments with the hydrated-lime and sulphur solution the coming season. It will be tested out on peaches and other fruits and we hope to determine whether or not this spray has any weak points or whether it is possible to modify formula so as to improve it.

SPRAYING SCHEDULE FOR INSECTS AND FUNGOUS DISEASES OF THE PEACH

No.	Pest	Time of Application	Spray Material
1.	Scale insects. Scab. Peach leaf curl. Brown rot.*	Dormant season.	Standard winter strength lime-sulphur. Use 1 gallon solution to 8 gallons water.
2.	Scab. Brown rot. Curculio.	As soon as chucks fall.	Hydrated-lime and sulphur, formula above, or 8-8-50 formula self-boiled lime-sulphur. Add 1lb powdered or 2lb paste lead arsenate to each 50 gallons of solution.
3.	Scab. Brown rot. Curculio.	Two weeks later than No. 2.	Same as No. 2.
4.	Brown rot.	One month before fruit ripens. Late varieties middle of July.	Hydrated-lime and sulphur, according to formula above, or self-boiled lime-sulphur, 8-8-50 formula.
5.	Brown rot. Late varieties.	Middle of August.	Same as No. 4.

* Destroy mummies before applying winter spray. In case of very early varieties sprays Nos. 1 and 2 may be all that are necessary. For all but extra early varieties spray No. 3 is extremely important.